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# PENETRATION IN OBJECTIVES.

## Is it a Defect or an Advantage?

By C. M. Vorce, F. R. M. S.

This subject has, for a few years past, received considerable and increasing attention from microscopists, but, so far as can be judged from published results, without resulting in an agreement of opinion or even a well defined conclusion. Much of the difference of opinion regarding penetration centers around the long waged controversy between the advocates of narrow-angled and of wide-angled objectives, and doubtless springs from the idea so frequently expressed, that low-angled objectives have penetration and high-angled ones have not. I am not prepared to say just how far this is true; but if it be true, it is doubtless owing to the fact that the superiority of wide-angled objectives in resolving power has stimulated the efforts of the opticians in the improvement of objectives, by widening their angle of aperture, in the direction of resolving power alone. I believe that it is possible to construct objectives of wide angle with a considerable degree of both resolving power and penetration, although if resolving power is to be pushed to its utmost limit penetration must be correspondingly sacrificed. During the past year some able papers touching on this subject have appeared in various publications, treating the subject in its theoretical aspects; and by way of antithesis I propose, in this paper, to treat the subject solely in a practical way.

Penetration in an objective is understood to be that quality by which it is enabled to present images of different planes in such near superposition and with such distinctness as to enable the eye to simultaneously receive and distinguish them. The images presented to the eye by such an objective impress the appearance of bulk and substance upon the mind, and in some measure resemble the images of natural objects formed by the unaided eye, from which necessarily our ideas of such objects are formed; and there is no doubt that the appearance presented to the eye of such an objective gives the mind instantaneously a correct idea of the relative position and arrangement of the parts whose images are thus seen.

With an objective in which penetration has been sacrificed to definition until *perfect* definition has been obtained by the sacrifice of all penetration, exactly the opposite effect is obtained. The image presented by such an objective is of a single plane absolutely, and no idea of relation of structure is conveyed to the mind by the image itself. The most minute of cognizable structures has some appreciable dimension and substance, but only an image of what is absolutely flat could be formed by such an objective, in which we suppose all the qualities except that of penetration to be brought to perfection.

If this be accepted as settled, it is still urged as an objection to penetration that it is not compatible with the best, or in other words, with *perfect* definition ; and the cry resounds that " defining power is the best attribute of an objective," and that the objection which affords the best definition of an object is the best, and venerable authorities are cited to that effect. Now, I believe it to be true that the objective which gives the best definition of an object is the best; but what is the best definition of an object? and what do the authorities cited mean by good definition ?

Definition ordinarily means description, and the definition of an objective is really nothing else than the clearness and completeness with which it describes to the mind by means of the image it presents to the eye, the characteristics of the object under inspection. Does showing the size alone, or shape alone, of an object, define it ? By no means. Does showing the shape and size combined define it? Certainly not fully. Definition of the edge is not necessarily definition of the object. To define an object requires the shape and size to be disclosed, and also the texture, structure and relation of parts to each other to be made clearly apparent. The objective which shows, not one alone, but *all* of these things the best, I regard as the best defining glass. Yet the theory seems to be advocated by some that the best defining glass is that which gives the sharpest definition of the finest line, or in other words, which focuses in as near a single plan as possible, and projects the images of the subject as nearly as possible in the same plane and without superposition.

Now, the practical questions recurs : which of these two objectives is the best, not for particular or special uses, but generally, practically, and for the most uses ? To decide that question we must first answer this, what is the purpose of any objective ? or rather, what purpose is it which every objective is intended to serve ? The obvious answer is, to render visible to the eye what without its aid would be invisible; which means, to enable the eye to perform its function to the mind in regard to those objects which without such aid it could not perceive at all.

In respect to the objects which are within the unaided power of the eye the mind receives its impressions in such manner as to instantaneously define not only particular characteristics of the object, but also its characteristics of relation, such as size, shape, location, etc., and this results from the combination of the qualities of both the objectives we have considered, viz.: penetration and definition. It has been urged that the eye has not much of this quality of penetration, but depends as to ordinary vision upon its power of accommodation of focus, and the durability of retinal images; but as this accomodation is instantaneous, it is obvious that the result is the same as if the lens had true penetrating power, and enables the eye to utilize the faculty of penetration or superposition of image possessed by an objective.

To enable the eye to communicate to the mind readily and reliably the full characteristics of an unknown object requires that the impression created be similar to that which the eye is accustomed to receive and which the mind is accustomed to recognize, and this requisite necessitates that an objective which transmits to the eye an image of an object having bulk and dimension, to render that image reliably and correctly cognizable by the mind must have penetration. The process followed by the mind is the same when an eye is aided by an objective as when it is not, and this process is first to note the general appearance of the object and relative situation or arrangement of its parts, and next to inspect and determine the characteristics of the details separately. As an illustration, suppose an observer for the first time to view a strange expanse of country. At the first glance the eye, in consequence of its penetrating power, notes the general features of the country, the mountain ranges, their intermediate valleys, the fact that the hills are wooded or not, and their general contour and relative positions to each other, and such general details of arrangement, but does not at the same glance give perfect definition of the minute structure of the separate features; after this general observation is impressed upon the mind, the eye dwells with less penetration but greater defining power on the details separately; and it is then observed whether the hills or ridges be smooth or furrowed with ravines, whether fully wooded or with open spaces, whether rocky or not, and what kind of timber it is that covers them; in short, the *details are defined* and added to the former general picture, still plain upon the mind, so quickly as to form a single *comprehensive* but still *definite* mental image of the whole, in which not only the minute details, but their relative arrangement are impressed upon the mind as a single view, complete in itself.

Compare the image and idea of structure and arrangement thus obtained by the mind with that which it would obtain by successive views of definition without penetration. In such case the mind would receive successive impressions of distinct objects, which themselves would be plainly and sharply defined, but without any apparent relation to each other; and this relation would have to be laboriously deduced by the mind by repeated reviews of the same objects and same sets of objects, and by argumentatively correlating the various objects one with the other. It is true that the resulting idea thus slowly and laboriously obtained by the mind *might* at the end be as correct as that obtained instantaneously by the other method; but it is not likely to be, or to state it more mildly, it is possible that it will not be.

Now, the same result that would be true of the unaided eye will be true of the eye when supplemented by the objective; in the one case the image presented to the eye will at once impress upon the mind characteristics of the object which, in the other case, the mind must laboriously piece out from fragments, with a percentage of chance for error.

It is no escape from this position to say that penetration may be allowed in low powers, but should be got rid of in high powers, for truly good definition, *i. e.* description is required in all powers, and certainly in high powers, for many objects can be viewed with no others, and if such objects are to be examined *only* with objectives of no penetration the results may well be distrusted. If it were practicable for the microscopist to have objectives of all powers, each suited to a special class of work, this controversy need never have been waged; but as it is the microscopist must put each of his objectives to varying classes of work, and what he requires in his glasses is the greatest range of work compatible with good performance. He is not equipped like the carpenter, who has a special tool for almost every stroke of work he does. He is more nearly in the situation of a carpenter who must do all his planing with one plane; in such a case it would be folly to select a plane suited only for exquisitely fine jointing.

But the opponents of penetration will point with pardonable pride to the resolution of lines and beads effected by the superb objectives to which they refer as models of definition. To this I say, the work is excellently well done, the resolution is exquisite, but the definition of the resolution I can not truly say I consider so excessively superior to that of many other objectives, and the definition of these same objectives aside from their resolution is good simply because they have not been deprived of penetration, and just to the extent that they combine penetration with resolution.

Nothing that I know of illustrates this more forcibly than the remarkable work performed by Dallinger and Drysdale, in 1878, in tracing out the complete life history of a new septic organism, and which work was a marvel of accurate original investigation upon a new and unknown form. Mr. Dallinger uses these words in describing the work and the means used: "Most of the more difficult and delicate work was done with an entirely new lens, by Powell & Lealand, nominally a 1-35 inch lens. It was made especially for this class of investigation, for which it is admirably adapted. Its working distance is sufficient, its penetration, for such power, is extremely great, its angle being moderate, and its definition is as sharp and clear, when properly used, as that of the finest 1-4 or 1-8." He also mentions that he had the use of four new formula lenses, a 1-8 of low angle and great penetrating power, and a 1-8, 1-12 and 1-16 of high angles, as well as his well-known 1-25 and 1-50. Further on Mr. Dallinger states that this wide-angled 1-16 had proved of great value in the detection of minute structure and change of form; but he immediately describes its failure to show details which he at once discovered with the penetrating 1-35, which he states to be the most suitable lens for the purpose, and which revealed to him, to use his own words again, "the most exquisitely minute particles which I have ever seen."

That the Rev. Mr. Dallinger is thoroughly conversant with the use of the widest-angled objectives, American as well as English, and in the resolution of diatoms, too, is well known to us all, and gives the greater significance to his preference for use in such exclusively delicate original investigations of objectives possessing a large degree of penetration.

The conclusion that I come to is this: we need both low powers and high powers, and we need them with penetration as well as with definition; we need penetrating high powers quite as much as we do defining high powers, and for delicate investigations neither one alone is sufficient. The work of Dallinger just referred to shows that the high power defining lens alone was unequal to the work, but when used as an ally to the high power penetrating glass, the two together successfully mastered the difficulty. Hence, I maintain that the true sphere of action and usefulness for high power non-penetrating objectives is the application of their wonderful defining power to the elaboration of details disclosed by penetrating objectives; in short, to supplement and crown the work of the other lenses, and, as it were, to *finish* the work which they are not qualified to do wholly and alone.

And the practical conclusion is, that the microscopist whose means permit should have both the penetrating and the defining glasses of both high and lower power; but if his means do not permit, then the widest range of usefulness within his means is compassed by the low power defining and the high power penetrating glasses, and to depend upon high power penetrating glasses alone is safer than to depend on a high power defining non-penetrating glasses alone for work solely within the reach of such powers, remembering, as we do, that high power glasses *can* have good penetration and very excellent, if not the absolutely best, definition; and the corollary of this proposition is that the makers of objectives should not expend *all* their efforts in developing definition at the expense of penetration, which fortunately they can not wholly get rid of, but devote some portion to developing the best attainable combination of penetration with definition in high power wide angled objectives.